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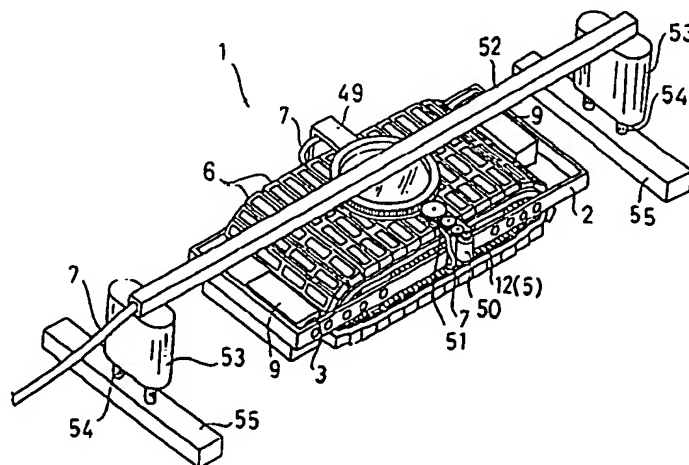
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(54) Robot travelling on a wall.

(57) A robot (1) travelling on a wall and capable of advancing or retreating on said wall in a stable manner and with a quick change-over of its travelling direction by means of a plurality of movable adsorption discs (6) designed for a close contact with the wall, and a pair of fixed adsorption rods (55), while commencing to be moved by drive motors (9), the adsorption force of these movable adsorption discs (6) being constantly so large that there is no risk of

dropping the robot (1) from the wall surface, in association with frictional resistance of each frictional surface of an antislipping member, promoting the touch between the robot (1) and the wall (A), thereby executing widely works on the wall in a safe manner instead of doing it by human workers, along with a loading of the robot (1) with a lot of instruments, if necessary.

FIG 1



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This invention relates to a robot travelling on a wall or along a ceiling surface of a construction such as a building, bridge and the like.

As well known, a robot travelling on a wall has been widely utilized for performing works, such as cleaning, inspection and coating of the wall of a construction including buildings, bridges and tunnels, which was risky even for experienced workers. This kind of robot travelling on the wall is found in the disclosure of Japanese unexamined patent application No. SHO (64)-5798.

The afore-mentioned disclosure is concerned with the liquid jet shut off unit mounted to a robot travelling on the wall. This known robot can travel on the wall by means of a pair of crawler type travelling vehicles having a plurality of adsorption discs formed on the crawler surface and the suction force generated from them is due to negative pressure which exists in the space formed between the adsorption discs and the wall under the principles of jetting compressed air from an ejector, which air is supplied by a piping from a compressor. Japanese unexamined utility model registration application No. HEI (01)-128475 and Japanese unexamined utility model registration application No. HEI (04)-38386, for example, disclose the movable adsorption disc used for the robot travelling on the wall.

The former application is concerned with improvements in the adsorption disc of the crawler type robot capable of moving on the wall and is characterized by disposing an inducing suction part in the adsorption disc, the inducing suction part aiming specifically at a promotion of the efficiency of the suction process performed just before the adsorption disc touches the wall surface.

The latter application discloses an object of providing another adsorption disc easy to adsorb as well as attainable to adhere, such merits being fulfilled by constructing the adsorption disc properly with a hard adsorption disc base made of hard elastic material and with the soft adsorption disc top end made of a soft elastic member.

But, a series of the afore-mentioned applications have debatable points. Namely, the model disclosed by the afore-mentioned Japanese unexamined patent application No. SHO (64)-5798 has a pair of crawler type travelling vehicles having a plurality of adsorption discs formed on the crawler surface to move the robot, necessity of two units of crawlers. The construction of disposing no adsorption disc in the space between the two units of crawlers reduces the adsorption surface, thereby making the adsorption force weaker.

Both of the movable adsorption discs mentioned in the afore-mentioned Japanese unexamined utility model registration application No. HEI (01)-128475 and Japanese unexamined utility

model registration application No. HEI (04)-38386 are constructed to make the adsorption against the wall easy as well as to attain the adherence to the wall constantly, the relative working efficiency being enhanced in the way of these applications. But, if these kinds of movable adsorption discs are used for the robot required for travelling on the wall, it happens easily that the adsorption disc slides on the wall due to a wet surface of the wall or due to the dead weight and it is difficult to use the robot in practice although it is easy to adsorb and/or to adhere constantly.

Means for overcoming the drawbacks:

First, the means comprises a pair of a 1st drive wheel and a 1st coupled follower wheel, opposite to each other with the predetermined distance left between them, each of which is disposed on one end side of a frame body, another pair of a 2nd drive wheel and a 2nd coupled follower wheel, also opposite to each other with the predetermined distance left between them as well as reversed in positions compared with the positions of the 1st drive wheel and the 1st coupled follower wheel, respectively, each of which is disposed on the opposite end side of the frame body, one unit of a rotatable belt which is wound around the afore-mentioned two pairs of drive wheels and coupled follower wheels to be rotated, being located at any of the one end side of the frame body and at another opposite end side thereof, a plurality of movable adsorption discs fixed onto the outer peripheral surface of the rotatable belt, a suction pipe connecting the movable adsorption discs and a vacuum equipment, and controllers, disposed in the middle section of the piping for the suction pipe, which is connected to the vacuum equipment at a touch of the movable adsorption disc to the wall surface or disconnect from the vacuum equipment at a separation of the movable adsorption disc from the wall surface. The first means causes the possibility of giving a constant tension to the rotatable belt, whose rotating motion is initiated preliminarily by being wound around two pairs of drive wheels and coupled follower wheels and whose position is led by the construction where two units drive wheels are not only disposed separately at the one end side of the frame body and another opposite end side thereof respectively but also reversed from each other in their positions along a diagonal of virtual quadrangle formed by two pairs of drive wheels and coupled follower wheels, to effect the distance between the rotatable belt and the wall surface to be constant. Thereby the adhesion to the wall surface is optimized, no matter whether the drive wheels are rotated in positive or negative direction, and allows an optional extension of lateral width of the movable adsorption disc much more than the clearance dis-

tance between the drive wheels and the coupled follower wheels. The reason is that the present means employs a construction, different from that of the conventional crawler type having two units of left and right crawlers, where one unit of a rotatable belt is provided and a plurality of movable adsorption discs are fixed onto the outer periphery of the rotatable belt, thereby enabling not only an enlargement of the adsorption area against the wall surface to be attained but also a resulting rise in the adsorption force between the robot and the wall surface. This leads to a maximization of the actuating performance or ability of the robot.

The second means is characterized by equipping the movable adsorption disc with a flexible enclosure frame and an antislipping member, movable within the enclosure frame, which is provided to be urged towardss the wall surface, and by an arrangement in which the suction force generated by the vacuum equipment provides a frictional surface of the antislipping member along which the touch between the antislipping member and the wall surface takes place to be contracted together with the enclosure frame against the urging force in a direction opposite to the wall surface. According to this means, the construction of the movable adsorption disc includes the flexible enclosure frame and the antislipping member, movable within the enclosure frame, which is provided to be urged towardss the wall surface and the mechanism of contracting the frictional surface of the antislipping member, where the touch between the antislipping member and the wall surface takes place, together with the enclosure frame in a direction opposite to the wall surface against the urging force, when the suction force is generated by the vacuum equipment to cooperate to enable the adhesion to be directed to the wall surface, generated by having contracted the enclosure frame, to make the inside of the enclosure frame approximately air-tight, resulting in a fulfillment of firm adsorption between the movable adsorption disc and the wall surface. At the same time, a large frictional force being produced by pressure from the close contact between the wall surface and the frictional surface of the antislipping member and the closed contact therebetween being initiated by a motion of the antislipping member against the urging force, prevents the movable adsorption disc from slipping on the wall surface. Since the stronger the suction force becomes, the more not only the pressure of close contact around the enclosure frame but also the frictional force arising against the urging force involved in the antislipping member are reinforced together, and the adsorption force can be increased as much as possible. On the other hand, when a separation of the movable adsorption disc from the wall surface is co-worked with a suspen-

sion of the suction from the vacuum equipment, the restoring force possessed by the enclosure frame returns the shape of the enclosure frame to the original shape thereof, also the antislipping member is returned to the original state, while the urging force moves the member towardss the wall surface within the enclosure frame.

The third means aims at an establishment of the posture where the frictional surface of the antislipping member becomes parallel with the wall surface just prior to the contact of the member with the wall surface, this designed aim being brought into reality by causing the movable adsorption disc to be fixed movably to and fro to the rotatable belt. According to the third means, the parallelism between the wall surface and the frictional surface, triggered just before the afore-mentioned contact therebetween, facilitates easily the adsorption to the wall surface.

The final means comprises a rotatable arm which is supported onto the frame body such that the arm can freely change over its direction, two units of vertically movable cylinders provided on both ends, respectively, of the rotatable arm, a pair of fixed adsorption rods each of which is fixed to either of the vertically movable cylinders, a suction pipe connecting the fixed adsorption rod and the vacuum equipment to each other, and a selector valve, disposed in the middle section of the piping for the suction pipe, for connecting and disconnecting the vacuum equipment and the fixed adsorption rod to/from each other. Specifically, the final means is concerned with operable steps including a change-over of direction of travelling the robot, a selection of travelling the robot towardss any desired destination along the wall and the like: When changing over a direction of travelling the robot, further to the first step of stretching the two units of vertically movable cylinders provided on both ends, respectively, of the rotatable arm, mounted to the frame body, in order to apply a pair of fixed adsorption rods, also provided on both ends, respectively, of the rotatable arm, to the wall surface, the step proceeds subsequently to a change-over of the selector valve so that the fixed adsorption rods and the wall surface may be connected by way of the vacuum equipment, comprising a vacuum pump and the like, and the suction pipe to each other and correspondingly to let the negative pressure take place from the fixed adsorption rods, resulting in an establishment of firm adsorption of the fixed adsorption rods onto the wall surface. Still further steps are directed to the disconnection of the movable adsorption discs and the vacuum equipment from one another and an additional stretching of the vertically movable cylinders, thereby detaching the movable adsorption discs from the wall surface and, after that, the robot body

is to be rotated in a desired travelling direction with respect to the rotatable arm. Next, operable steps required for travelling the robot towardss the desired destination along the wall include operations first in the order of applying the movable adsorption discs to the wall surface in association with a contraction of the vertically movable cylinders and letting the adsorption force take place with the help from connecting the vacuum equipment and the movable adsorption discs to one another for the adsorption of the movable adsorption discs onto the wall face and other operations partly permitting the selector valve to disconnect the fixed adsorption rods and the vacuum equipment and subsequently providing a still additional contraction of the vertically movable cylinder for a detachment of the fixed adsorption rods from the wall surface, the last simple process proceeding to rotate positively or negatively the rotatable belt, thereby directing the robot to any desired destination on the wall.

Other features and advantages will be apparent from the specification and claims and from the accompanying drawings which illustrate embodiments of the invention.

Fig. 1 is a perspective view of a robot of the present invention, travelling on wall surface with movable adsorption discs.

Fig. 2 is a plan diagram of the drive mechanism for the robot travelling on the wall surface.

Fig. 3 is a side diagram of the drive mechanism for the robot travelling on a wall surface.

Fig. 4 is a view illustrating the robot in travelling on a wall.

Fig. 5 is a perspective view illustrating partially the movable adsorption disc.

Fig. 6 is a sectional diagram taken on the line A-A of Fig. 5.

Fig. 7 is a sectional diagram of the movable adsorption disc being adsorpted on the wall surface.

Fig. 8 is a partially omitted diagram of a guide portion and an auxiliary guide portion of a robot.

Fig. 9 is a back view taken from a direction of arrow B of Fig. 8.

Fig. 10 is a sectional view of a state of mounting a controller and the movable adsorption discs to one another.

Fig. 11 is a perspective exploded diagram of a state of mounting the controller and the movable adsorption discs to one another.

Fig. 12 is a diagram of the controlling structure.

Fig. 13 is a sectional view taken on the line

C-C of Fig. 11.

Fig. 14 is a perspective diagram of the robot travelling on the wall according to another embodiment of the invention.

Fig. 15 is a sectional diagram taken on the line D-D of Fig. 14.

A description of embodiments of the invention is made in connection with the accompanying drawings as follows:

Referring first to Figs. 1-3, basically, the robot travelling on the wall surface comprises a pair of a 1st drive wheel 3 and a 1st coupled follower wheel 4, opposite to each other, which are provided on one end side of the frame body 2 to be spaced with a distance equal to the lateral width of the frame body 2 left theretwween, another pair of a 2nd drive wheel 3 and a 2nd coupled follower wheel 4, also opposite to each other, which are provided on another opposite end side of the frame body 2 to make each position of the 2nd drive wheel 3 or the 2nd coupled follower wheel 4 reversible to that of the 1st drive wheel 3 or the 1st coupled follower wheel 4 respectively, one unit of a rotatable belt 5 which is wound around the two afore-mentioned groups including a pair of the 1st drive wheel 3 and the 1st coupled follower wheel 4 and a pair of the 2nd drive wheel 3 and the 2nd coupled follower wheel 4 located at both end sides, respectively, opposite to each other, of the frame body 2, to be rotated, a plurality of movable adsorption discs 6 fixed to an outer peripheral surface of the rotatable belt 5, suction pipes 7 connecting the movable adsorption discs 6 and the vacuum equipment (not shown) to one another, and controllers 8, provided in the middle section piping of the suction pipe 7, which are actuated to connect and disconnect to/from the vacuum equipment at a contact between the movable adsorption discs and the wall surface and at a detachment of the movable adsorption discs from the wall surface, respectively.

A motor 9 is provided on one end side of the frame body 2 of rectangular shape and a rotational motion is transmitted by way of a drive gear 10 and intermediate gears 11, all of which are provided on the frame body 2 from the motor 9 to the drive wheel 3. It will be apparent from Fig. 12 that the drive wheel 3 has teeth formed on its outer periphery, whereby the teeth become in mesh with tooth portions 12 formed on the back face of the rotatable belt 5. On the other side of the frame body 2, opposite to the afore-mentioned drive wheel 3, the coupled follower wheel 4 having the diameter equal to that of the drive wheel 3 is rotatably provided, also the outer periphery of the coupled follower wheel 4 being equipped with the teeth to become in mesh with the tooth portions 12 of the rotatable belt 5. Another motor 9 is provided on the other opposite end side of the frame body

and, similarly to the afore-mentioned construction, on the other side corresponding to the position located at the opposite edge of the diagonal of the frame body 2 another drive gear 10, other intermediate gears 11 and another drive gear 3 are provided, the one side, opposite to the position of the last other drive gear 3, of the frame body 2 being equipped with another coupled follower wheel 4 such that the last other coupled follower wheel 4 may be rotatable.

A rotational drive is given from different sides one of which, located at the frame body 2, is equipped with a pair of a drive wheel 3 and a coupled follower wheel 4, opposite to each other, having teeth together for windable engagement with tooth portions 12 formed on the inner peripheral surface of the rotatable belt 5 and another of which, also located at the frame body 2, is equipped with another pair of a drive wheel 3 and a coupled follower wheel 4, opposite to each other, having teeth together for windable engagement with tooth portion 12 thereon to the rotatable belt 5. For this reason, irrespective of a positive or negative rotation as well as even when a rotational change-over is required, the rotatable belt 5 can maintain a tension so sufficiently that no slack of the belt 5 takes place, whereby the robot 1 can always hold its closed contact with the wall surface and allows the resulting rise in adsorption force to travel the robot 1 as stable as possible, whenever the travelling on the wall is required. Furthermore, the rotatable belt 5 is in mesh with four rotatable idler wheels 13 first two of which are located between a pair of a drive wheel 3 and a coupled follower wheel 4 on one end side of the frame body 2 and the remaining two of which are located between another pair of a drive wheel 3 and a coupled follower wheel 4 on another opposite end side of the frame body 2. Each of the diameters of these idler wheels 13 is larger than that of the drive wheel 2. Two control wheels 20, located at the centre of the frame body holding a shaft 19 in common, are driven by gears 14 fixed to axes of two of these four idler wheels 13 both of which, being separately located on one side or on the opposite side of the frame body, are close to the coupled follower wheels 4 respectively. Two units of 1st intermediate gears 15 and two units of 2nd intermediate gears 16 which are rotatably supported onto axes respectively are fixed to the frame body 2, and two units of 3rd intermediate gears 17 and two units of 4th intermediate gears 18 are coaxial together with the afore-mentioned two units of the 2nd intermediate gear 16. The engagement caused by these gear mechanisms can regulate a synchronization between one rotation of the control wheels 20 which may be transmitted from the idler wheels 13 thereto and one rotation of the

rotatable belt 5 to be attained under a arrangement of bringing a number of teeth of each control wheel 20 and number of tooth portions 12 of the rotatable belt 5 into coincidence.

As shown in Figs. 5 and 6, the construction of the movable adsorption disc 6 comprises a base plate 22 provided at the lower part of a enclosure frame 21 of rectangular shape being horizontally longer as well as made from an elastic synthetic rubber, a pedestal 24 with an air hole 23 provided in the enclosure frame 21, the antislipping member 26 of box the type, interposed between and surrounded by the pedestal 24, the enclosure frame 21 and the base plate 22 and located over the pedestal 24, which is urged to move in a direction opposite to the position of the pedestal 24 by elastic bodies 25 and a mounting frame 27 to which both the pedestal 24 and the base plate 22 are fixed.

Each antislipping member 26 of the box type, being provided in one of suction chambers 28 formed in inside of the enclosure frame 21, has its centre equipped with a through hole 30 communicating with the frictional surface 29, a plurality of suction grooves 31 being formed to be intersected one another on the frictional surface 29 with the through hole 30 crossed by them. Consequently, for example, a illustration of Fig. 7 might help to clarify an mechanical arrangement required for a touch of the robot with the perpendicular wall surface A, in which upon commencement of suction from the air hole 23 by way of a movable suction pipe 32 to the area out of the illustration, the air is sucked in through a passage including the suction groove 31, the through hole 30 and the air hole 23, and the antislipping member 26 is caused to move towardss the pedestal 24 located oppositely to the wall surface A against an action by the urging force from the elastic body 25, such a movement of the antislipping member 26 being correspondingly accompanied with a sealing between the wall surface A and the enclosure frame 21 which is concurrently contracted. This acts as a trigger for the adsorption between the frictional surface 29 of the antislipping member 26 and the wall surface A to complete an adherence to the wall surface A. As to the quality of the antislipping member 26, the optimum material is wood, but also other materials may be used. Figs. 5 and 6 illustrate details of the mounting frame 27. Each of the ends located in a relatively longer direction of the mounting frame 27 is equipped with a perpendicular piece 33 bent down in a direction opposite to the position of the enclosure frame 21, and a horizontal piece 34 is further bent outward from the end of the perpendicular piece 33, the perpendicular piece 33 being furnished with a 1st guide wheel 35 and a 2nd guide wheel 36 having shafts, respectively, different in

length from each other, with positions of these guide wheels 35 and 36 being parallel to the horizontal piece 34. In addition to a 3rd guide wheel 37 rotating at a position wherein its rotating direction is in a right angle to each of the rotation directions of the 1st and 2nd guide wheels 35 and 36 is provided under the horizontal piece 34. Fig. 10 makes clear that the back face of each mounting frame 27 is rotatably fixed through a hinge 38 to the outer peripheral surface of the rotatable belt 5 by means of screws and the like and a slight gap between adjacent mounting frames 27 causes the angle of rotating them in a free manner to be smaller.

Referring then to Figs. 8, 9, and 10, in a side where the frame body 2 faces the wall surface A a linear guide rail 39 for guiding the three guide wheels 35, 36, and 37 on the mounting frame 27 is disposed. The linear guide rail 39 aims not only at a equal distribution of force acting upon an occurrence of detachment of the frame body 2 from the wall surface A because of unbalanced load applied against the robot travelling on the wall surface at a constant parallel state between the movable adsorption discs 6 fixed on the outer peripheral surface of the rotatable belt 5 and the wall surface A to all the movable adsorption discs 6, but also at the prevention of the robot from oscillating to right or left from its planned travelling direction, when the rotatable belt 5 is in mesh with two pairs of drive wheels 3 and coupled follower wheels 4 and two pairs of idler wheels 13 for being rotated. For this reason the guide rail 39 has a 1st guide 40 for guiding the 1st and 2nd guide wheels 35 and 36 in a direction parallel with the wall surface A and a 2nd guide 41 for guiding the 3rd guide wheel 37 in a direction perpendicular to the wall surface A. It will be apparent from Figs. 8 and 9 that an auxiliary guide rail 42 of circular shape is provided to run from the lower part of each of the idler wheels 13 located at both ends of the afore-mentioned linear guide rail 39 to the lower part of the drive wheel 3 or the coupled follower wheel 4. Also apparently, the auxiliary guide rail 42 is used for correcting a posture of the frictional surface 29 of the antislipping member 26 of the movable adsorption disc 6 which is going to be just prior to its touch with the wall surface so that the frictional surface 29 thereof may become parallel with the wall surface A. The 1st guide wheel 35 having a relatively longer shaft, provided on the perpendicular piece 33 of the mounting frame 27, is guided by a convex face of circular shape of the auxiliary guide rail 42, whereby the movable adsorption disc 6 is rotated with the hinge 38 as a centre to establish the parallel state concerned. On the other hand, to prepare for the reverse rotation in advance, the same kind of auxiliary guide rail 42 is provided in the opposite end side and, in such a case of the reverse rota-

tion, the 2nd guide wheel 36 having a relatively shorter shaft is guided by the convex face of circular shape of the latter auxiliary guide rail 42. For this reason, the latter auxiliary guide rail 42 is provided closer to the mounting frame 27 in an extent equal to a distance produced by the shorter length of the shaft of the 2nd guide wheel 36.

Each controller 8 comprises basically a controlling wheel 20, a controlling plate 43 fixed to the frame body 2, and a selector plate 44, movable to and fro, which is interposed between the controlling wheel 20 and the controlling plate 43. 15 lines of groups each of which includes 4 units of round holes 46 are spaced with the angular intervals left equally between them in a radial direction from a centre hole 45 penetrating by the shaft 19 the outer periphery of the controlling wheel 20. A line of 4 round holes 46 has them associated correspondingly with 4 units of air holes 23 respectively on one of the movable adsorption discs 6, the flexible movable suction pipes 32 connecting individually these round holes 46 and air holes 23 on the movable adsorption disc 6 to one another. Generally, at least 30 units of movable adsorption discs 6 are fixed on the outer peripheral face of the rotatable belt 5 so that a corresponding relation between 15 lines of round holes 46 on one controlling wheel 20 and the half number, i.e. 15 units, of the movable adsorption discs 6 is established, further resulting in managing two units of controlling wheels 20 to correspond to the overall movable adsorption discs 6. For promotion of the safe actuation, after all, the adjacent movable adsorption discs 6 come in a corresponding relation with one line of round holes 46 respectively located on each of the two different controlling discs 6, whereby even outbreak of any accident causing a damage to either of the controllers 8 will enable a state of adsorbing the half number of movable adsorption discs 6 to the wall face A to be maintained. The afore-mentioned gear mechanism allows two units of controlling wheels 20, opposite to each other, to be rotated together in the same direction at the same speed and also their rotation being forced to arise the same direction at the same speed under an arrangement of fixing each of them to the shaft 19 which has, as mentioned above, its both ends supported rotatably on the frame body 2. Furthermore, these two controlling wheels 20 and the rotatable belt 5 are arranged to be rotated in the same direction as well as to have mutually the same number of teeth, whereby, in addition to a resulting synchronization of rotating the rotatable belt 5 by one turn every one turn of rotating the controlling wheel 20, no shaft corresponding to the shaft 19 between the drive wheel 3 and the coupled follower wheel 4 exists to move rotatably 120 units of movable suction pipes 32 connecting the

round holes 46 on the controlling wheels and air holes 23 respectively of the movable adsorption disc 6 without a mutual entanglement of the movable suction pipes 32.

The controlling plate 43 is fixed by way of the selector plate 44 to the frame body 2 such that the controlling plate 43 becomes concentric to each controlling wheel 20. Packings are put into sections respectively among the controlling plate 43, the selector plate 44, and the controlling wheel 20 to make these sections air-tight. The suction pipe 7 to which a suction through hole 47 of circular shape, formed on the controlling plate 43, is connected causes the air to be sucked by way of the selector plate 44 from all the round holes 46 on the controlling wheel 20 upon locating of the round holes 46 at the suction through hole 47. In general, 11 units of movable adsorption discs 6 are adapted to be adsorbed towards the wall surface A constantly under an arrangement of numbering in 11 lines of round holes 46 in total, located on the suction through holes 47 respectively of the two units of controlling plates 20, specifically while the round holes 46 on one side run in 6 lines, whereas the round holes 46 on another side run in 5 lines. Since the selector plate 44 is also equipped with a suction hole 48 of the same shape as that of the suction through hole 47, the suction force from the suction pipe 7 is conveyed towards each movable adsorption disc 6, flowing through passage including the controlling plate 43, the selector plate 44, the controlling wheel 20 and the movable suction pipe 32. A further construction is that the rotation of a control motor (not shown), fixed to the frame body 2, whose gears are in mesh with the gears formed on the outer periphery of the selector plate 44 causes the controlling wheel 20 to be rotated only by an angle made by 2 lines of round holes 46 with each other with the shaft as a centre, i.e. the controlling wheel 20 is triggered to be rotated by a distance ranging from a position illustrated by dashed line X in Fig. 12 to a position illustrated by two-dot chain line Y, thereby changing over the adsorption position of each movable adsorption disc 6. As a result, among 11 units of movable adsorption discs 6 in a suction process a primary movable adsorption disc 6 which is going to perform the suction process is changed over its position and the movable adsorption disc 6 at the front row of direction of advancing the robot travelling on the wall surface 1 becomes constantly sucked in.

Either a vacuum pump, or a type of device for supplying the compressed air and sucking in the same under the principles of an ejector may be used as the vacuum equipment. As the installation place of the vacuum equipment, any place including a higher place as the rooftop of the construc-

tion a part of which forms the wall surface A, a ground, or a loading of the robot 1 with the equipment may be acceptable. If the afore-mentioned higher place is used, a connection between the vacuum equipment and the robot 1, achieved by the suction pipe 7, may be advantageous for preventing the robot 1 from dropping by means of utilizing the suction pipe 7 instead of a lifeline, even if a remarkable lowering of the suction force by the movable adsorption discs 6 arises which lowering makes it impossible to adsorb the robot 1 against the wall surface A.

When advancing the robot 1 along the wall surface A of a construction like a building, first of all, the initially required steps are only to let the frictional surfaces 29 of 11 units of movable adsorption discs 6, located at the lower part of the robot come into contact with the wall surface A and to connect these movable adsorption discs 6 with the vacuum equipment (not shown). Then, the 11 units of movable adsorption discs 6 which are connected through the suction through holes 47 of circular shape on the two controlling plates 43, the suction holes 48 on the selector plates 44, 11 lines of round holes 46 in total, located correspondingly at these two suction holes 48 respectively, and 44 units of round holes 46 in total, running similarly in 11 lines, all of which are made on the two controlling wheels 20, and the movable suction pipes 32 from the suction pipe 7, facing the wall surface A, will be sucked in to reduce pressure in 44 units of suction chambers 28 in total on the movable adsorption discs 6 and to maintain a close contact between the movable adsorption discs 6 and to maintain a close contact between the frictional surfaces 29 of the antislipping members 26 and the wall surface A, thereby avoiding a drop of the robot from the wall surface A. Furthermore, when the antislipping member 26 in each suction chamber 28 causes the enclosure frame 21 of the movable adsorption disc 6 to be contracted upon the suction process, the frictional surface of each antislipping member 26 comes into close contact with the wall surface A to reinforce the frictional force against the wall surface A, thereby maximizing the security of avoiding the robot 1 to drop from the wall surface A. With a plurality of suction chambers 28 provided in the movable adsorption disc 6 as mentioned in the present embodiment, the suction process is performed independently from each suction chamber 28. Accordingly, even in case of an accident which causes damages to any suction chamber 28 and/or to any movable suction pipe 32 in respect of sucking in the atmospheric air, the invention provides the advantage of safety since a drop of the robot 1 from the wall surface A is avoided.

In order to commence to travel the robot 1 along the wall surface A, an initial step is to supply current into the electric wire which is connected to the power supply and bundled together with the suction pipe 7 which is connected to the vacuum equipment (not shown). This causes two units of motors 9 to be driven in a positive or negative direction. The two units of drive wheels 3 each of which is located at either of both diagonals are in turn rotated at the same time to rotate the rotatable belt 5. At that time the controlling wheels 20 in mesh with the afore-mentioned gear mechanism with two of the four units of idler wheels 13 which are engaged with the rotatable belt 5 commence also to rotate. As mentioned above, the controlling wheels 20 are adapted to be sucked in only from 11 units of movable adsorption discs 6 located on the wall surface A, so no sucking-in from the movable adsorption discs 6 located at the front and rear ends or at the position opposite to the wall surface A is generated, resulting in an effective utilization of the suction force from the vacuum equipment. One of 11 units of movable adsorption discs 6 to perform the sucking-in process during travelling the robot 1 not only starts the sucking-in process slightly prior to its touch with the wall surface but also is moved to and fro with the hinge 38 as a centre just before its touch therewith by the help of the auxiliary guide rail 42, the 1st guide wheel 35 or the 2nd guide wheel 36, so that each frictional surface 2 becomes parallel with the wall surface A, thereby making the adsorption against the wall surface A relatively easier.

When changing over the travelling direction of the robot 1 into a reverse direction, the first step is to drive a control motor (not shown) to rotate the selector plates 44 only by a distance equal to the angle made with the two adjacent lines of round holes 46, whereby, among 11 units of movable adsorption discs 6 for sucking-in, the afore-mentioned reasons cause still the movable adsorption disc 6 just before its touch with the wall surface A to perform the sucking-in process to make the adsorption against the wall surface A easier. Additional steps of rotating the motors 9 in a reverse direction to drive the two units of drive wheels 3 similarly to the afore-mentioned arrangement and of causing the rotatable belt 5 to be rotated in a reverse direction, allow the robot 1 to advance in a reverse direction. Thus, a series of the sucking-in processes, performed continuously by the movable adsorption discs facing the wall surface A and/or controls by the controllers 8 for stopping the sucking-in process of the movable adsorption discs 6 to be detached from the wall surface A will enable the robot 1 to travel back and forward.

Depending on application modes, the frame body 2 of the robot 1 of the afore-mentioned con-

structions may be flexibly furnished with an applicator, a cleaner, a coating unit and the like for the wall surface A to execute multi-works. In cases wherein the robot 1 can change-over to a travel direction other than its forward or backward during the works, the working efficiency is improved to a remarkable extent. So it is preferable to equip the frame body 2 with a direction selector unit.

As shown in Fig. 1 the direction selector unit comprises a rotatable arm 52, being able to change its direction by means of a swivelling motor 50 and a gear train 51, which is supported by way of a fixed arm 49 onto the upper part of the frame body 2, a pair of vertically movable cylinders 53 provided on both the ends respectively of the rotatable arm 52, a pair of fixed adsorption rods 55 fixed to rods 54 respectively of the vertically movable cylinders 53, the suction pipe 7 connecting these fixed adsorption rods 55 and the vacuum equipment (not shown), and a selector valve (not shown), provided in the middle course of the pipings for the suction pipe 7, for connecting and disconnecting the vacuum equipment and the fixed adsorption rods 55 to/from one another. The vertically movable cylinders 53 are connected to the suction pipe 7 such that the sucking-in generated inside of them enables the rods 54 to be vertically controlled. The construction of the fixed adsorption rods 55 is the same as that of the movable adsorption discs 6.

When actuating the afore-mentioned direction selector unit for a change-over of the advancing direction of the robot 1, further to an extension of rods 54 of the pair of vertically movable cylinders 53 provided on both ends respectively of the rotatable arm 52 to trigger the fixed adsorption rods 55 to be in contact with the wall surface A, a negative pressure must be generated in the fixed adsorption rods 55, connected by way of the suction pipe 7 to the vacuum equipment with a selector valve (not shown) being switched so that a firm adsorption of the fixed adsorption rods 55 against the wall surface A may be established, and thereafter upon a disconnection of the movable adsorption discs 6 from the vacuum equipment the rods 54 of the vertically movable cylinders 53 are adapted to be additionally extended to detach 11 units of movable adsorption discs 6 from the wall surface A. Then the robot 1 rotates in a new desired advancing direction relatively to the rotatable arm 52. At that time, a corresponding driving of a swivelling motor 50 will transmit rotational force to the gear train 51, resulting in its rotation. Subsequently, a contraction of the rods 54 of the vertically movable cylinders 53 will cause 11 units of movable adsorption discs 6 to come into contact with the wall surface A and the commencement of such a contact therebetween in turn proceeds to the following step of generating an adsorption force by means of a

connection between the vacuum equipment and the movable adsorption discs 6 for an initiation of a firm adsorption of them to the wall surface A. Vice versa, a disconnection of the vacuum equipment from the fixed adsorption rods 55 by means of actuating the selector valve is to be followed by the final step of contracting still additionally the rods 54 of the vertically movable cylinders 53 for a detachment of the fixed adsorption rods 55 from the wall surface A, simply driving of the two units of motors 9 being required to rotate the rotatable belt 5 in a positive or negative direction, thereby completing the steps of leading the robot 1 to be advanced in the desired direction.

Figs. 14 and 15 illustrate another embodiment, wherein a moving unit effective in case of requiring the robot travelling on the wall surface A to be moved only in a lateral direction due to the necessity of having any work done by the robot 1. According to this embodiment, a construction includes vertically movable cylinders 53 provided on both the ends respectively of the frame body 2 of the robot 1 by means of mounting arms 56, the fixed adsorption rods 55 of longer length being mounted to the top ends of rods 54 of the aforementioned vertically movable cylinders 53, each of the upper surfaces of the fixed adsorption rods 55 and each of the top ends of the rods 54 being constructed to be slidable to each other in association with sliding plates 57, and, additionally, an engagement between drive gears 58 provided on both the ends of the frame body 2 and teeth 59 formed along the inner sides of the two units of fixed adsorption rods 55.

Thus, the construction of the embodiment will enable the robot 1 to be moved in a lateral direction by means of operations in order to adsorb and fix the fixed adsorption rods 55 to the wall surface A, actuating the vertically movable cylinders 53 for detachment of the robot 1 from the wall surface A, and finally driving the drive gears 58.

It is apparent from the afore-mentioned description that the robot travelling on the wall according to the invention includes a pair of drive wheel and coupled follower wheel, opposite to each other, which are provided on one end side of the frame body with the specified distance left therebetween, another pair of drive wheel and coupled follower wheel, also opposite to each other, which are provided on another opposite end side of the frame body, while disposing the drive wheel, as one element of the latter pair, at a position diagonally reverse to that of the drive wheel, as one element of the former pair, whereas the coupled follower wheel, as another resting element of the latter pair, is disposed in a manner reversed to the position of the coupled follower wheel, as another resting element of the former pair, in the same

manner, and a plurality of movable adsorption discs mounted onto one unit of rotatable belt which is wound around the two pairs of drive wheels and coupled follower wheels for rotation, whereby a possibility of giving drive forces to the rotatable belt from both sides along which the two pairs of drive wheels and coupled follower wheels are disposed together having the rotatable belt wound around them as mentioned above will assure a stable travelling of the robot. A merit produced by the invention lies, first of all, in the maximization of the adsorption force to the wall surface and in the extension of the range of loading the robot with a lot of working instruments, both of which originate from the enlargement of the area of the overall face where a plurality of movable adsorption discs, fixed to the outer peripheral surface of the one unit of a rotatable belt, comes into contact with the wall surface.

A further merit is the possibility to load the robot travelling on the wall with a lot of instruments, because a plurality of movable adsorption discs has an enclosure frame made of flexible material, and each antislipping member can be moved and forced to a direction towards the wall surface, which antislipping member is provided in the enclosure frame, and each frictional surface of the antislipping member is designed to come into direct contact with the wall surface and is constructed to be contractable together with the enclosure frame in a direction opposite to the wall surface against the urging force by means of the sucking-in force from the vacuum equipment, and the enclosure member results in being firmly adhered to the wall surface during the adsorption time in cooperation with its elasticity, the urging force helping each frictional surface to be in close contact with the wall surface and to increase its frictional resistance at the same time so that the adsorption force and the frictional resistance are increased.

Still a further merit is that it is easy to achieve an adsorption to the wall surface in terms of posture of each frictional surface of the antislipping member, taken just before the touch to the wall surface, wherein it becomes parallel with the wall surface.

Claims

1. A robot travelling on a wall characterized by a pair of drive wheel (3) and coupled follower wheel (4), opposite to each other, which is provided on one end side of a frame body (2) with a specific distance left therebetween, another pair of drive wheel and coupled follower wheel, also opposite to each other, which is on another opposite end side of said frame body (2) with a specific distance left there-

between such that said drive wheel, as one element of the latter pair, is disposed at a position diagonally reversed to that of said drive wheel (3), as one element of the former pair, whereas said coupled follower wheel, as another resting element of the latter pair, is located at a position reversed to that of said coupled follower wheel (4), as another resting element of the former pair, in the same manner as in the case of said latter drive wheel, one unit of a rotatable belt (5) which is wound around these two pairs of drive wheels and coupled follower wheels, each of the pairs of elements being disposed at either of one end side or another opposite end side of said frame body (2), so that said rotatable belt (5) may be rotated,

a plurality of movable adsorption discs (6) fixed to the outer peripheral face of said rotatable belt (5),

a suction pipe (7) connecting said adsorption discs (6) with a vacuum equipment, and controllers (8), provided in the middle of the pipings for said suction pipe (7), for making a connection with said vacuum equipment upon contact between said movable adsorption discs (6) and said wall face (A) and/or disconnecting said connection with said vacuum equipment upon detachment of said movable adsorption discs (6) from said wall face (A).

2. A robot according to claim 1, wherein a plurality of movable adsorption discs (6) include an enclosure frame (21) made of an elastic material, and antislipping members (26) which can be moved and forced to approach a wall face direction, provided within said enclosure frame (21) and a suction force from a vacuum equipment permits each frictional surface (29) to come into contact with said wall face (A) and to constitute each antislipping member (26) to be contracted together with said enclosure frame (21) in a direction opposite to said wall face (A) against an urging force.

3. A robot according to claim 1 or 2, wherein a plurality of movable adsorption discs (6) is fixed to a rotatable belt (5), made in a manner of having said movable adsorption discs (6) moved to and fro, as well as permits each frictional surface (29) of said antislipping member (26) to take a posture where said frictional surface (29) becomes parallel with the wall face (A) just before its contact therewith.

4. A robot according to any of the preceding claims, wherein said robot (1) comprises a rotatable arm (52) supported changeably in its

actuating direction onto a frame body (2), vertically movable cylinders (53) provided on both ends respectively of said rotatable arm (52), fixed adsorption rods (55) fixed to said vertically movable cylinders (53) respectively, a suction pipe (7) for connecting said fixed adsorption rods (55) with a vacuum equipment, and a selector valve, provided in the middle of the pipings for said suction pipe (7), for connecting and disconnecting said vacuum equipment and said fixed adsorption rods to/from each other.

FIG 1

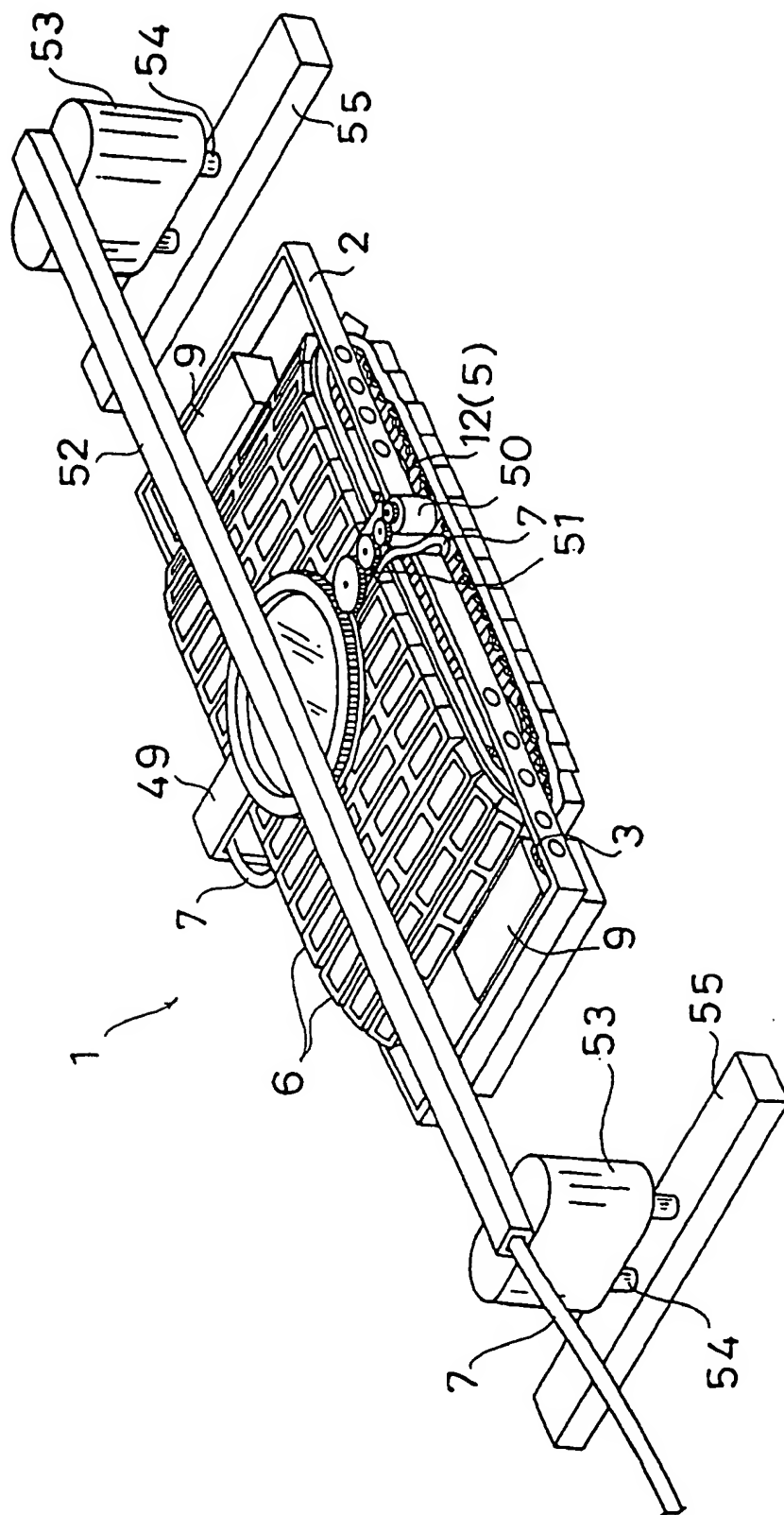


FIG 2

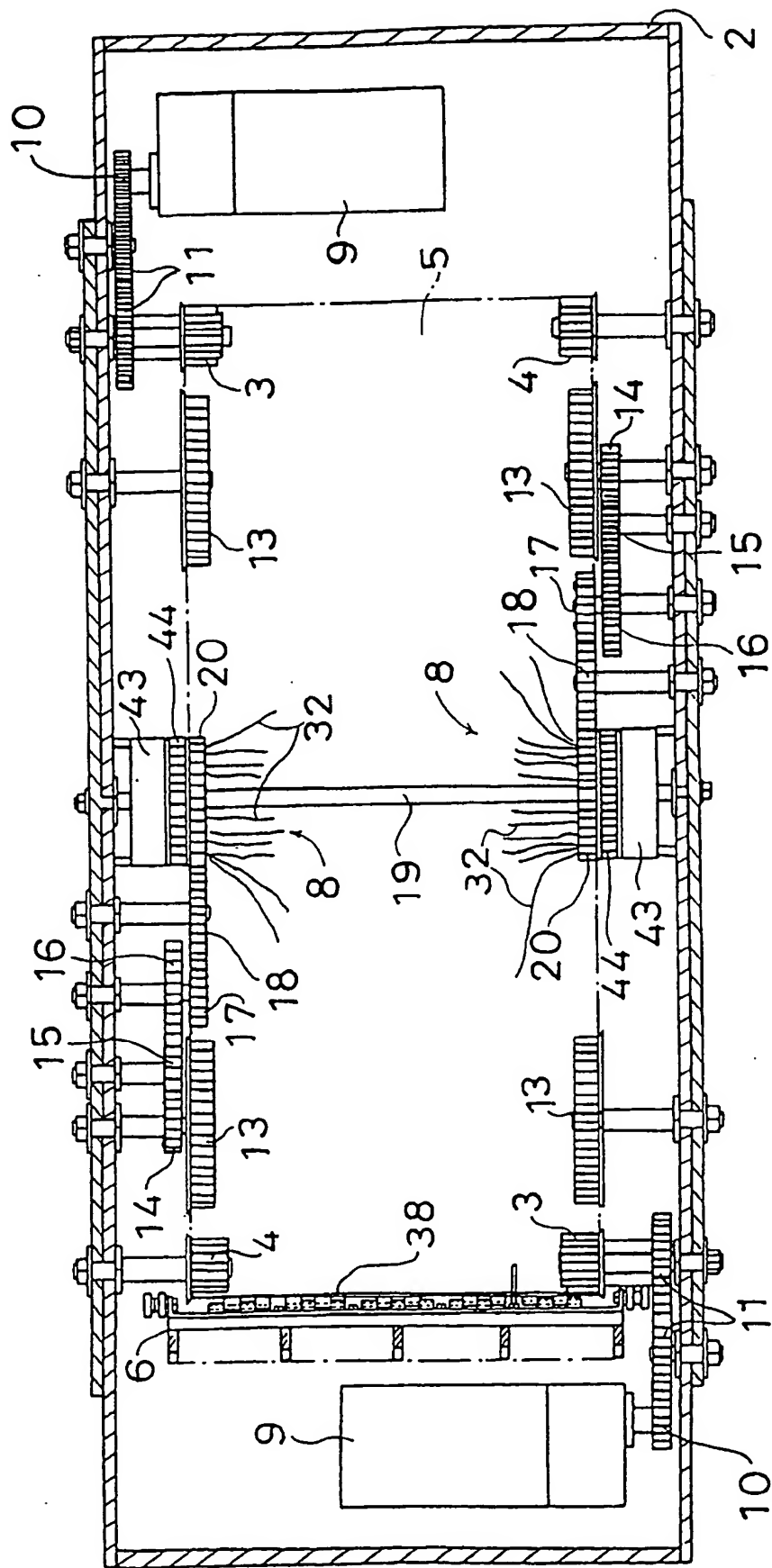


FIG 3

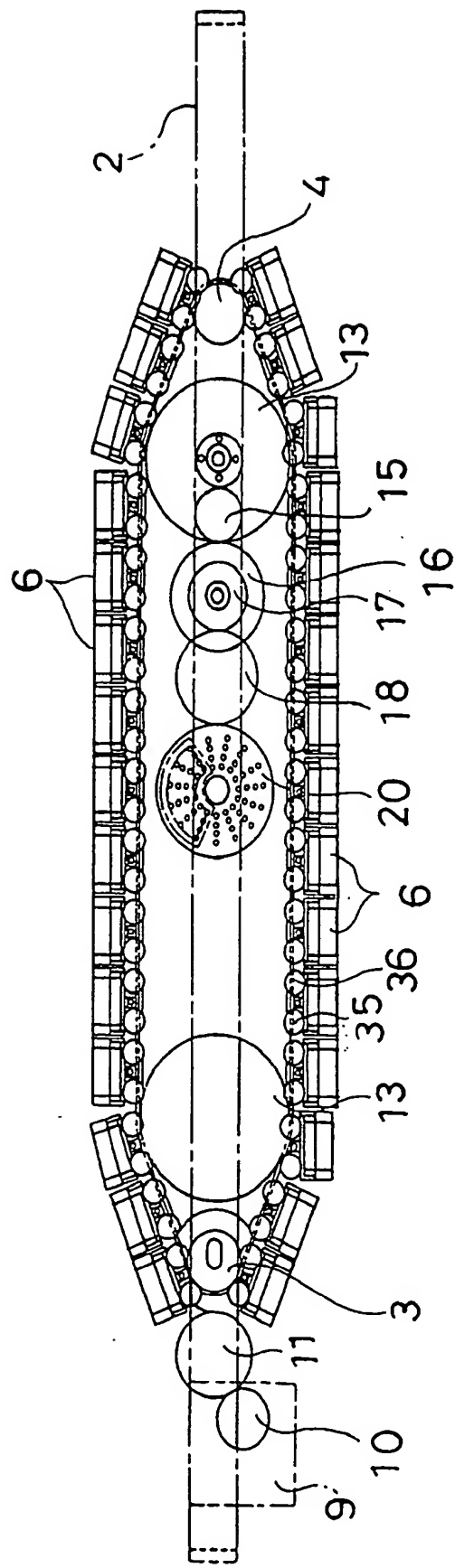


FIG 4

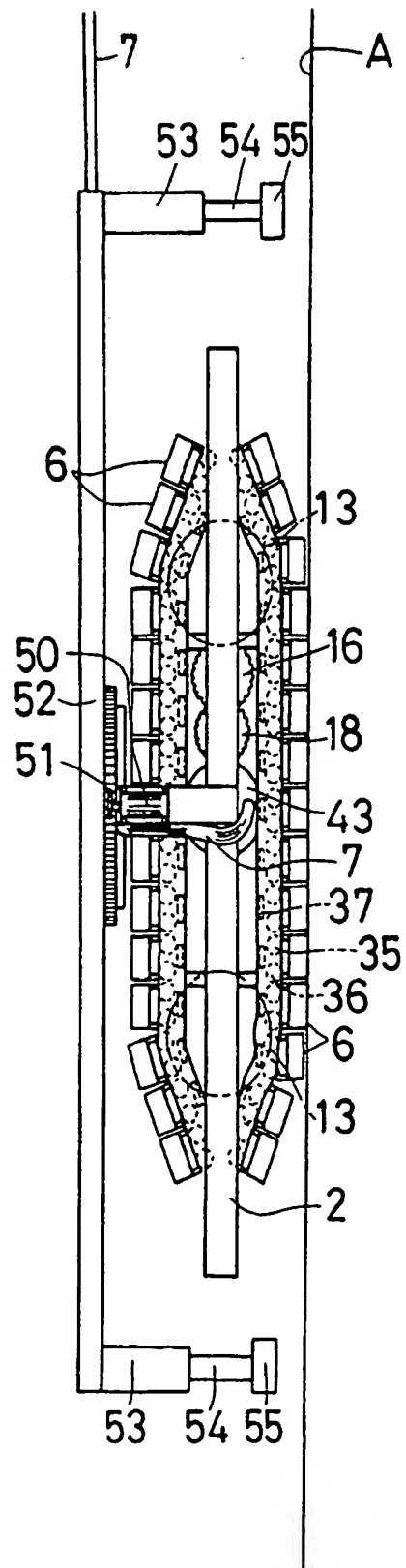


FIG 5

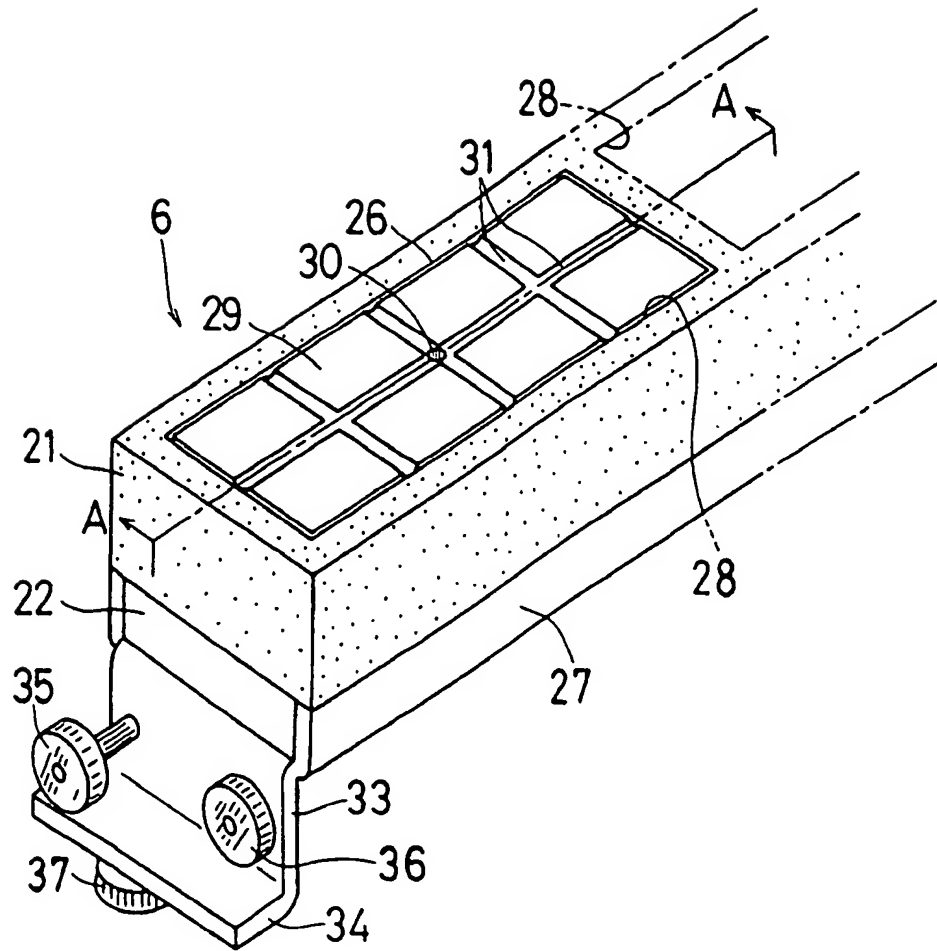


FIG 6

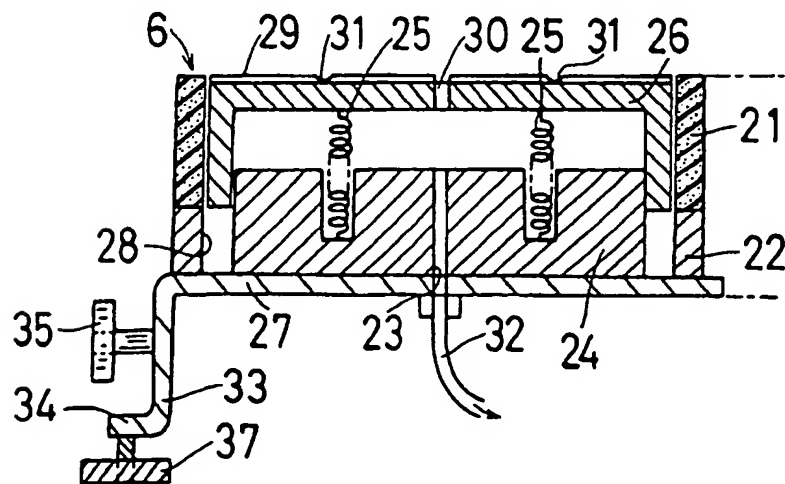


FIG 7

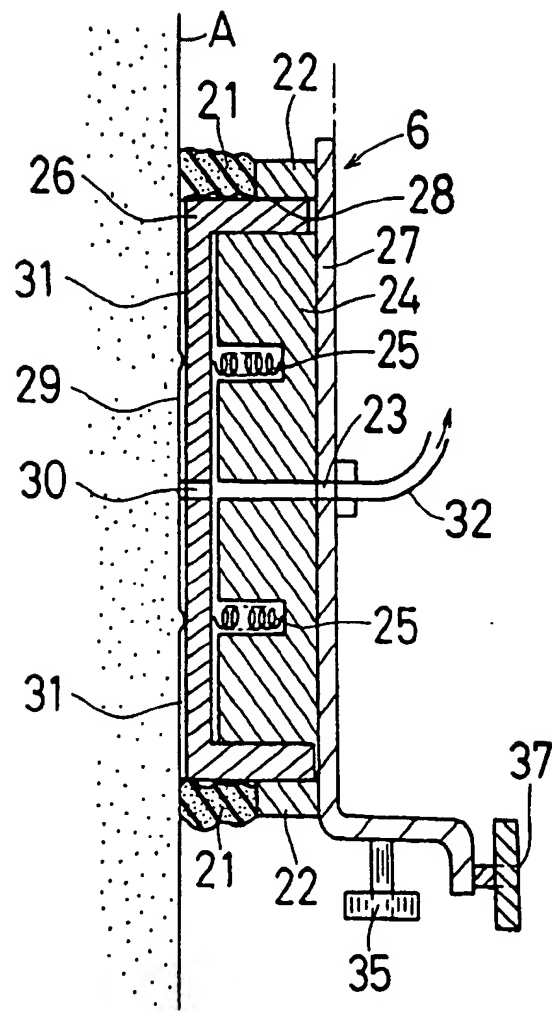


FIG 8

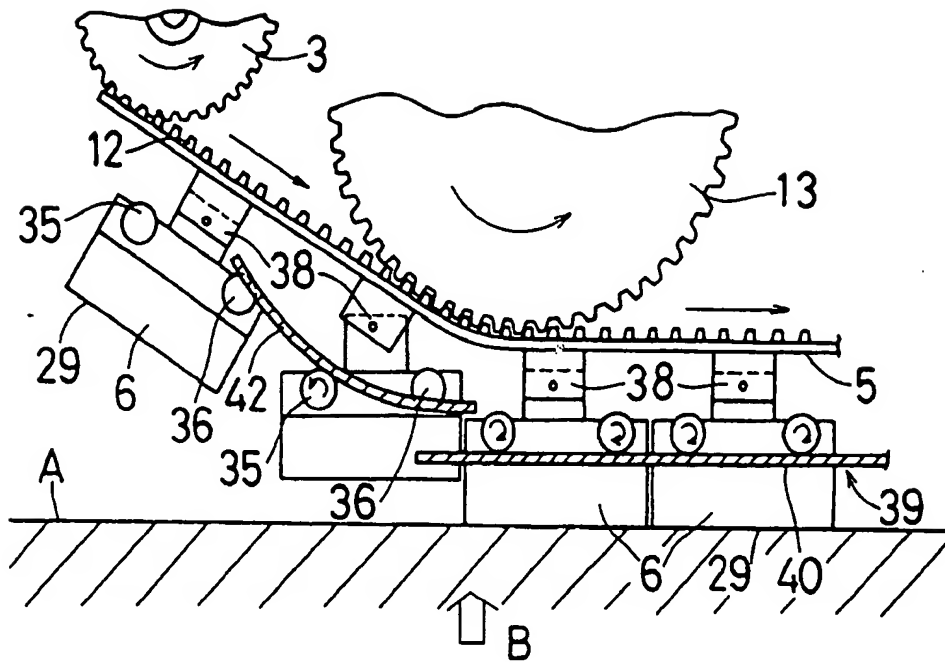


FIG 9

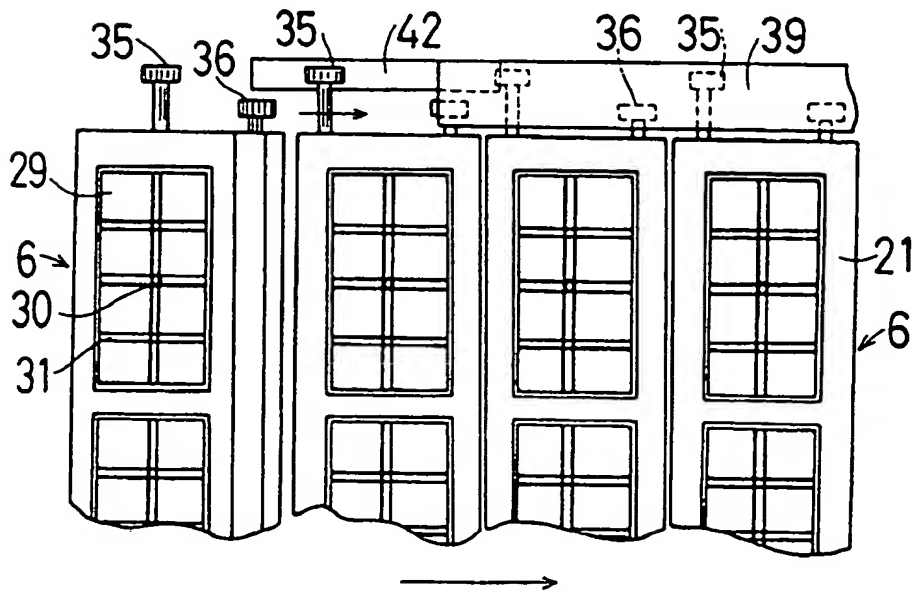


FIG 10

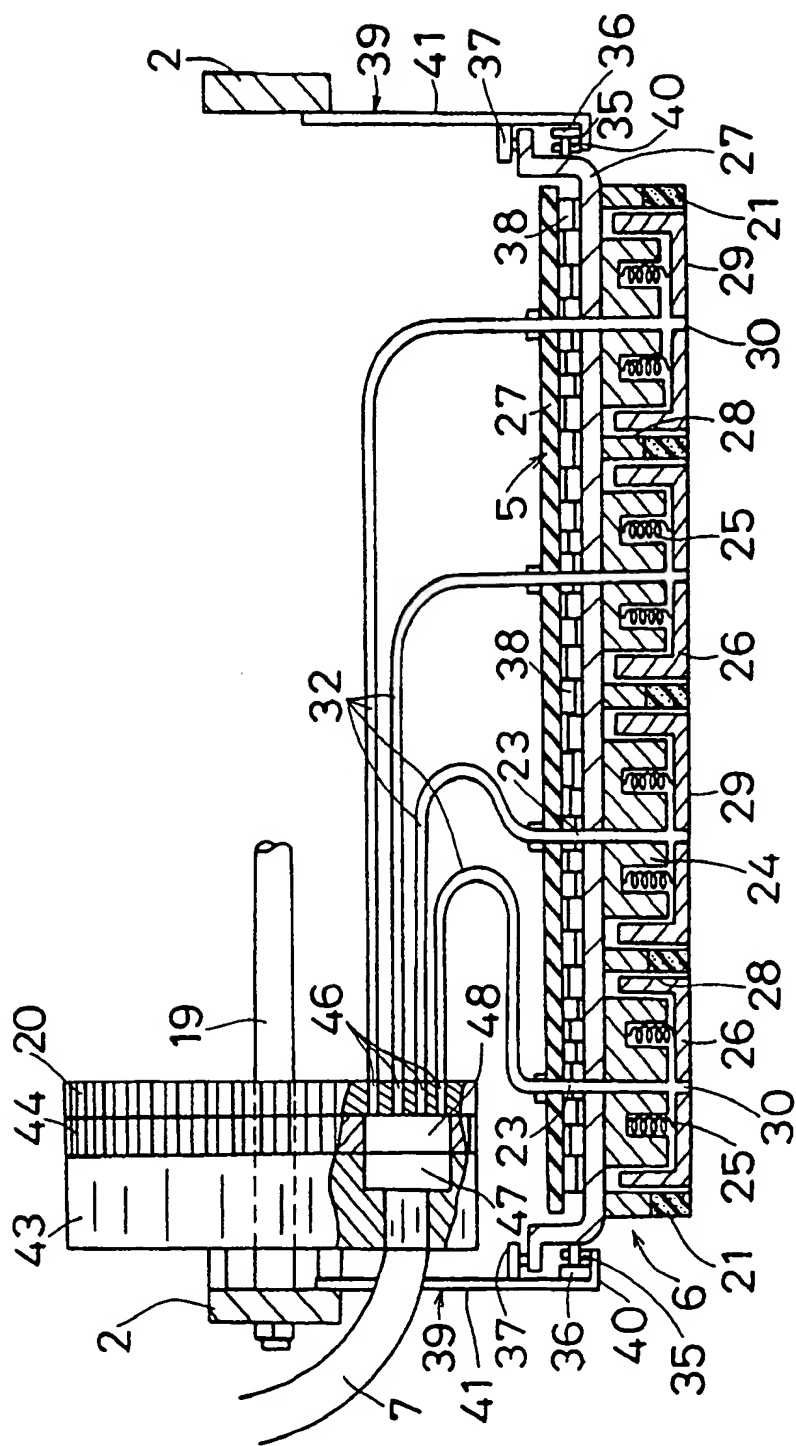


FIG 11

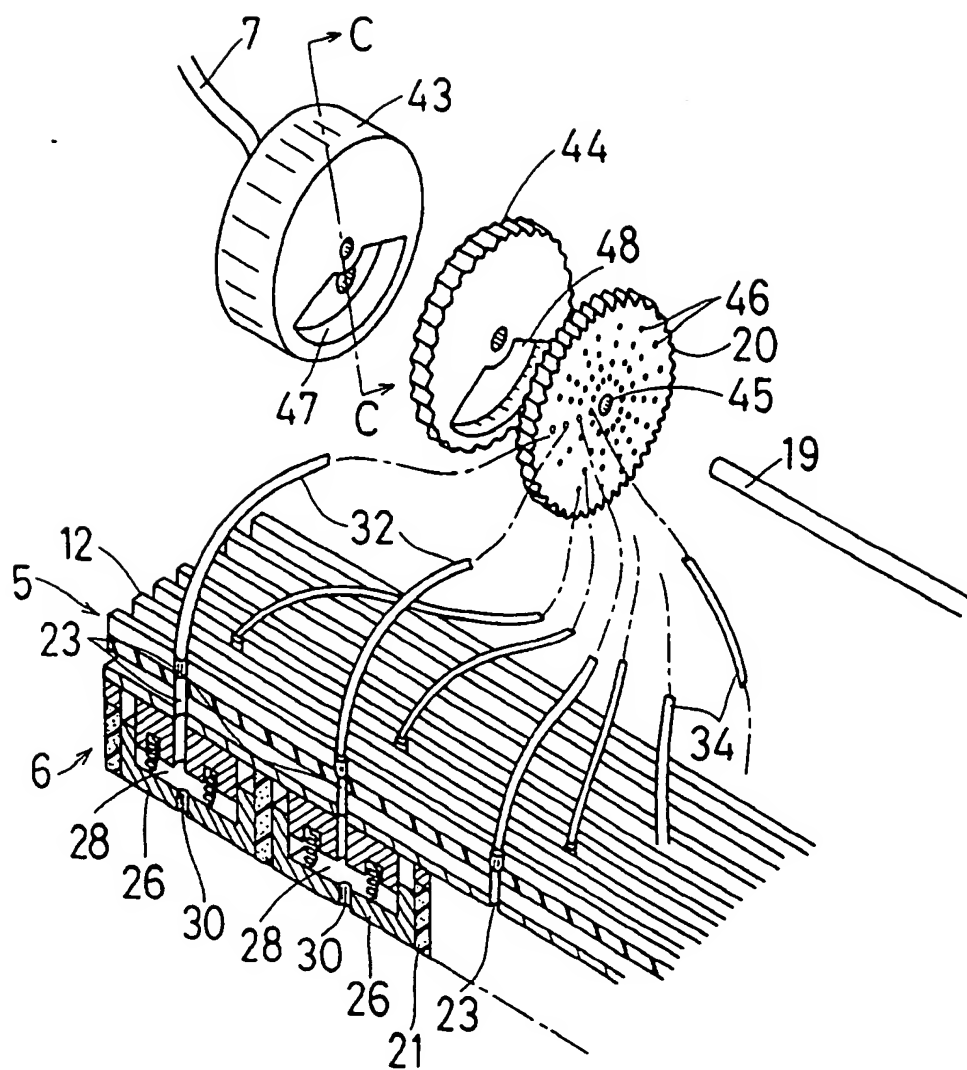


FIG 12

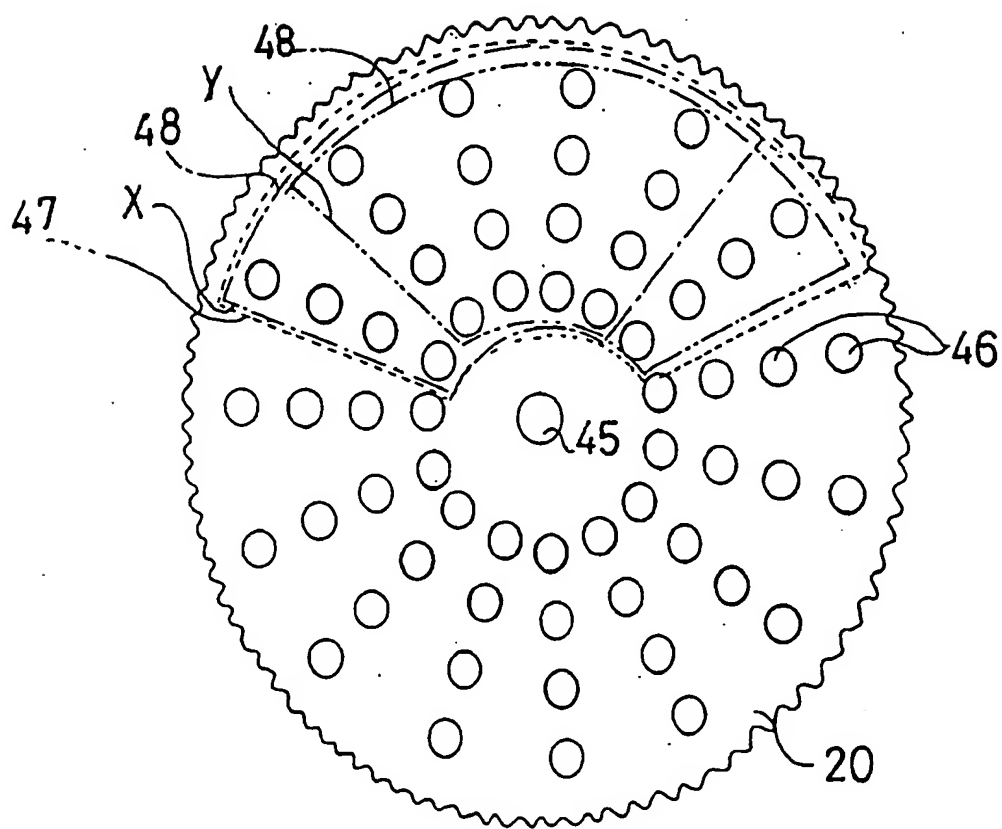


FIG 13

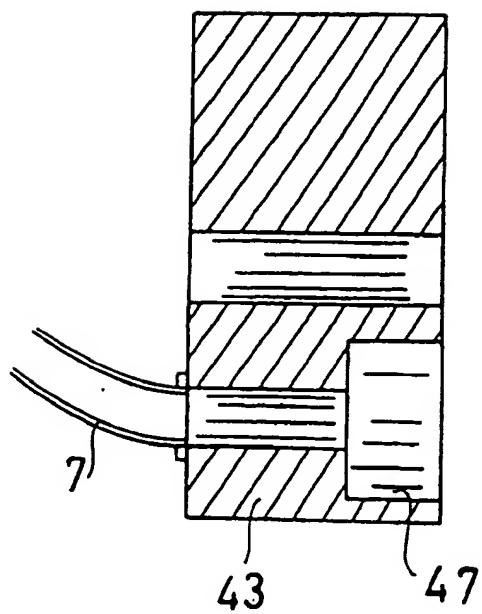
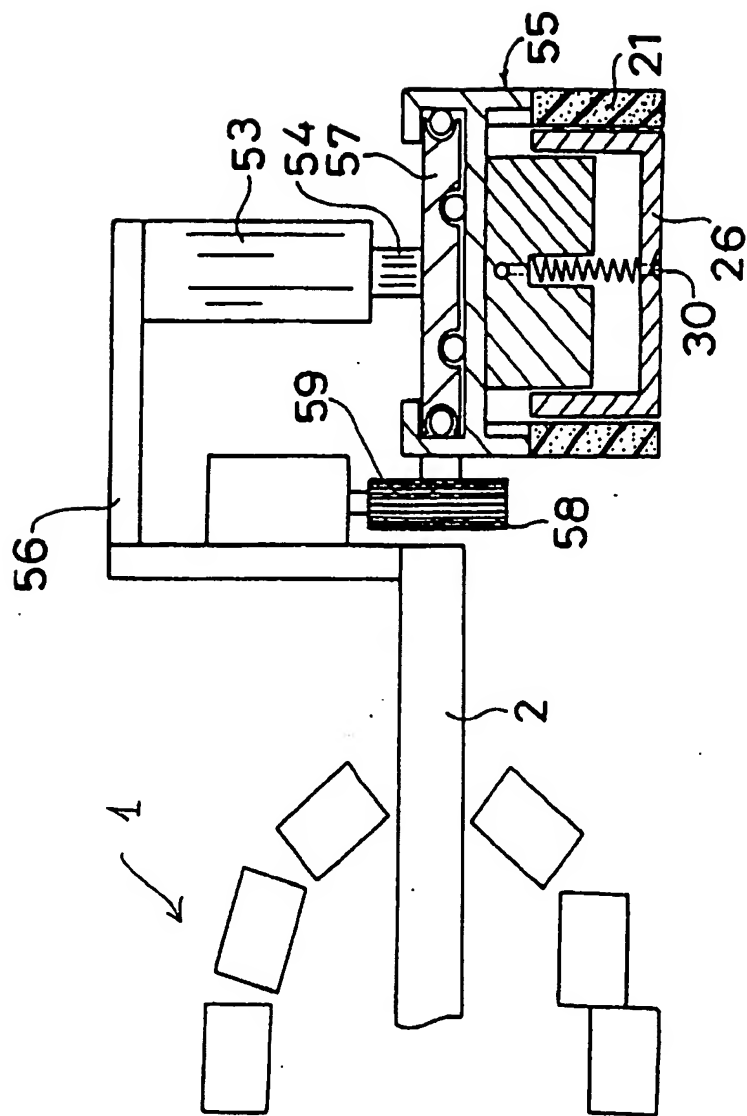


FIG 15





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number

EP 93 11 1478

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Y	FR-A-1 288 375 (VORMEZELEE) * page 4, left column, paragraph 5 * * page 5, right column, paragraph 4 - page 6, left column, paragraph 2; figures 17,18,29-31 *	1-3	B62D55/07 B62D55/265
Y	GB-A-2 164 010 (MITSUBISHI ET AL.) * the whole document *	1-3	
A	FR-A-1 352 056 (INSTITUT FUR SCHIFFBAU) * page 2, right column, paragraph 3; figures 5,6 *	1	
A	PATENT ABSTRACTS OF JAPAN vol. 11, no. 39 (M-559)(2486) 5 February 1987 & JP-A-61 205 568 (HITACHI) * abstract *	1,2	
A	US-A-4 699 252 (SING) * column 6, line 64 - column 7, line 57; figures 3,4,5,8 *	1,2	
A	DE-A-3 312 222 (RAUSCH) * abstract; figure 1 *	1	
A	EP-A-0 407 745 (O.N.O. ET AL.) * the whole document *	1,2	
A	WO-A-8 502 135 (DALSEIDE) * abstract; claims 1,2,8; figures 1-3 *	1-3	
A	US-A-3 777 834 (HIRAOKA ET AL.) * abstract; figures 1,2 *	1,4	
The present search report has been drawn up for all claims			
Place of search BERLIN		Date of completion of the search 30 NOVEMBER 1993	Examiner KRIEGER Ph.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons A : member of the same patent family, corresponding document			

EP FORM 1503 01.92 (P0401)



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VERSION CORRIGEE

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applicant addresses
Adresses du 1er inventeur et
demandeur erronées**

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Mention of correction in Patent Bulletin No.
Mention de la correction dans le bulletin n°

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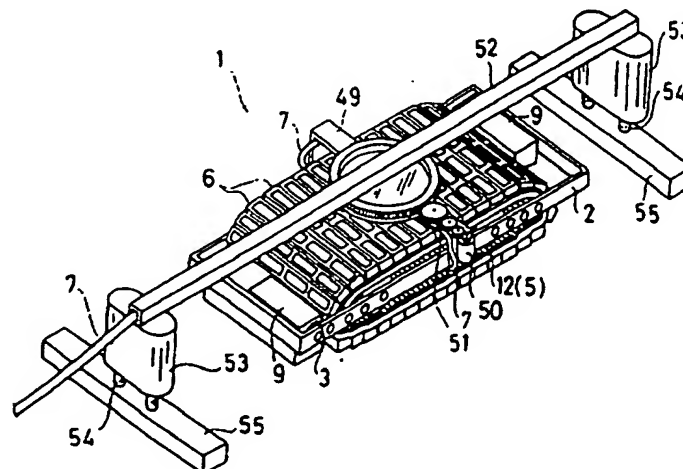
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Robot travelling on a wall.

A robot (1) travelling on a wall and capable of advancing or retreating on said wall in a stable manner and with a quick change-over of its travelling direction by means of a plurality of movable adsorption discs (6) designed for a close contact with the wall, and a pair of fixed adsorption rods (55), while commencing to be moved by drive motors (9), the adsorption force of these movable adsorption discs (6) being constantly so large that there is no risk of

dropping the robot (1) from the wall surface, in association with frictional resistance of each frictional surface of an antislipping member, promoting the touch between the robot (1) and the wall (A), thereby executing widely works on the wall in a safe manner instead of doing it by human workers, along with a loading of the robot (1) with a lot of instruments, if necessary.

FIG 1



This invention relates to a robot travelling on a wall or along a ceiling surface of a construction such as a building, bridge and the like.

As well known, a robot travelling on a wall has been widely utilized for performing works, such as cleaning, inspection and coating of the wall of a construction including buildings, bridges and tunnels, which was risky even for experienced workers. This kind of robot travelling on the wall is found in the disclosure of Japanese unexamined patent application No. SHO (64)-5798.

The afore-mentioned disclosure is concerned with the liquid jet shut off unit mounted to a robot travelling on the wall. This known robot can travel on the wall by means of a pair of crawler type travelling vehicles having a plurality of adsorption discs formed on the crawler surface and the suction force generated from them is due to negative pressure which exists in the space formed between the adsorption discs and the wall under the principles of jetting compressed air from an ejector, which air is supplied by a piping from a compressor. Japanese unexamined utility model registration application No. HEI (01)-128475 and Japanese unexamined utility model registration application No. HEI (04)-38386, for example, disclose the movable adsorption disc used for the robot travelling on the wall.

The former application is concerned with improvements in the adsorption disc of the crawler type robot capable of moving on the wall and is characterized by disposing an inducing suction part in the adsorption disc, the inducing suction part aiming specifically at a promotion of the efficiency of the suction process performed just before the adsorption disc touches the wall surface.

The latter application discloses an object of providing another adsorption disc easy to adsorb as well as attainable to adhere, such merits being fulfilled by constructing the adsorption disc properly with a hard adsorption disc base made of hard elastic material and with the soft adsorption disc top end made of a soft elastic member.

But, a series of the afore-mentioned applications have debatable points. Namely, the model disclosed by the afore-mentioned Japanese unexamined patent application No. SHO (64)-5798 has a pair of crawler type travelling vehicles having a plurality of adsorption discs formed on the crawler surface to move the robot, necessity of two units of crawlers. The construction of disposing no adsorption disc in the space between the two units of crawlers reduces the adsorption surface, thereby making the adsorption force weaker.

Both of the movable adsorption discs mentioned in the afore-mentioned Japanese unexamined utility model registration application No. HEI (01)-128475 and Japanese unexamined utility

model registration application No. HEI (04)-38386 are constructed to make the adsorption against the wall easy as well as to attain the adherence to the wall constantly, the relative working efficiency being enhanced in the way of these applications. But, if these kinds of movable adsorption discs are used for the robot required for travelling on the wall, it happens easily that the adsorption disc slides on the wall due to a wet surface of the wall or due to the dead weight and it is difficult to use the robot in practice although it is easy to adsorb and/or to adhere constantly.

Means for overcoming the drawbacks:

First, the means comprises a pair of a 1st drive wheel and a 1st coupled follower wheel, opposite to each other with the predetermined distance left between them, each of which is disposed on one end side of a frame body, another pair of a 2nd drive wheel and a 2nd coupled follower wheel, also opposite to each other with the predetermined distance left between them as well as reversed in positions compared with the positions of the 1st drive wheel and the 1st coupled follower wheel, respectively, each of which is disposed on the opposite end side of the frame body, one unit of a rotatable belt which is wound around the afore-mentioned two pairs of drive wheels and coupled follower wheels to be rotated, being located at any of the one end side of the frame body and at another opposite end side thereof, a plurality of movable adsorption discs fixed onto the outer peripheral surface of the rotatable belt, a suction pipe connecting the movable adsorption discs and a vacuum equipment, and controllers, disposed in the middle section of the piping for the suction pipe, which is connected to the vacuum equipment at a touch of the movable adsorption disc to the wall surface or disconnect from the vacuum equipment at a separation of the movable adsorption disc from the wall surface. The first means causes the possibility of giving a constant tension to the rotatable belt, whose rotating motion is initiated preliminarily by being wound around two pairs of drive wheels and coupled follower wheels and whose position is led by the construction where two units drive wheels are not only disposed separately at the one end side of the frame body and another opposite end side thereof respectively but also reversed from each other in their positions along a diagonal of virtual quadrangle formed by two pairs of drive wheels and coupled follower wheels, to effect the distance between the rotatable belt and the wall surface to be constant. Thereby the adhesion to the wall surface is optimized, no matter whether the drive wheels are rotated in positive or negative direction, and allows an optional extension of lateral width of the movable adsorption disc much more than the clearance dis-

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